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Soil Management Systems in a Young Bartlett Pear Orchard

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SOIL MANAGEMENT SYSTEMS IN A YOUNG BARTLETT PEAR ORCHARD

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INTRODUCTION

The problem of soil management systems for tree fruits has received almost continuous attention from an experimental viewpoint during the last 25 years. The resultant conclusion is that no one cultural system is adapted to all orchards or to all climatic conditions. With our present knowledge of type of soil, depth of tree rooting, factors affecting root growth, and soil-plant moisture relationships, the limitations of each system are becoming more apparent and the conditions to which each system of soil management is best adapted are better understood.

Systems of soil management for the pear have always been decidedly influenced by those in vogue for the apple, and, as might be predicted, the pear has gained as well as suffered from this dependence. The cultivation with cover crops system, generally considered as very acceptable for the apple, has consequently been applied to the pear as well. In this connection Tukey (19) made the following statement in 1928: "Clean cultivation early in the season followed by a good cover crop sown the middle of July is to be strongly recommended. There are peculiar conditions which call for modification but the vast majority of orchards will find this practice best."

As time passed the greater susceptibility of the pear to the ravages of the fire-blight organism has caused some question as to the ultimate benefit of the cultivation with cover crops system. It has been frequently observed that changing to the sod system (usually with nitrogen added) has reduced the severity of the blight. On the other hand, the reverse change has frequently increased the injury. The desirability of a more restrained type of growth than is commonly obtained by cultivation with cover crops led Chandler (3) in 1925 to suggest the use of the sod system with nitrogen added.

Chandler concluded that some sacrifice in tree growth must necessarily be made if the susceptibility of the pear to blight was to be reduced. To what extent a slight reduction in growth is followed by an appreciable sacrifice in yield is an interesting question. To be sure, it is known that within fairly wide limits the yield of tree fruits increases with the growth of the tree, but whether a small reduction in growth from a rather vigorous level results invariably in a significant reduction in yield is not so certain.

In view of this uncertainty, questions have arisen as to the relative effect of the various systems of soil management upon tree growth and the extent of crop reduction resulting from reduced growth.

In consequence, the experiments reported herein were designed to determine the effect of several systems of soil management upon growth and fruiting. In view of the recent rather dry years the grass or straw mulch system has become increasingly important with the apple in certain areas in the East. Naturally, some knowledge of its application to pear culture becomes important. In general, it seemed desirable to compare the relative effects under Ohio conditions of grass or straw mulch, bluegrass sod with added nitrogen, and the cultivation with cover crops systems.

[1]The author wishes to express his appreciation of the cooperation of M A Bachtell, in charge of the District and County Experiment Farms, and L. A Malik, Superintendent of the Northeastern Experiment Farm, Strongsville, in this work.

LITERATURE REVIEW

There are no experiments in the literature concerning the various systems of soil management for the pear. Chandler (3) had suggested the use of sod with added nitrogen where blight was a serious factor. Tukey (19), after stating that cultivation is the best practice for the majority of orchards, declares "grass cut and allowed to lie or spread around the trees may be advantageous on rough or stony land or land which is unusually well supplied with moisture". He added further that legume covers, such as alfalfa, have not been sufficiently tested to determine their value but suggested that too great tree vigor might be their disadvantage. Kinman and Magness (12) stated recently that the use of permanent cover crops has not become popular for pears where water supply is a limiting factor. They conclude that even in the West, where abundant water is available, alfalfa is usually disked in the spring so that its growth will not interfere with fruit setting and with shoot growth.

PLAN AND ESTABLISHMENT OF THE EXPERIMENT

The trees in the experiment were of the Bartlett variety and were planted in late May 1929 at the Northeastern Experiment Farm of the Ohio Agricultural Experiment Station, at Strongsville, 16 miles south of Cleveland. Two-year-old trees were carefully selected and pruned to the modified leader system with one leader and four laterals. These trees were planted 20 feet by 20 feet in a block 15 rows long by 15 trees wide. The trees of the fifth and eleventh rows were of mixed varieties for pollinizing purposes.

The land occupied by the trees was divided into 15 plots, ten having 12 trees and five having 15 trees each (Fig. 1). The treatments were five in number and were triplicated as follows:

Treatment A—Plots A-1, A-8, A-15.
: Cultivation with cover crop. Plowed in early spring. Cover crop of oats and vetch seeded about July 1.

Treatment B—Plots B-2, B-7, B-14.
: Kentucky bluegrass sod, with nitrate of soda applied in early April.

Treatment C—Plots C-3, C-6, C-13.
: Kentucky bluegrass sod with grass cut and used as mulch around trees. Nitrate of soda and straw added annually since 1934. Fertilizer applied late March or early April.

Treatment D—Plots D-4, D-10, D-12.
: Alfalfa sod cut and left lying each year until 1934. Used as mulch around trees since 1934.

Treatment E—Plots E-5, E-9, E-11.
: Cultivation with cover crop. Disked in early spring. Cover crop of oats and vetch seeded about June 15.

TYPE OF SOIL

The soil in the test orchard is classified as the Mahoning silty clay loam. Conrey and Paschall (6) describe this type as characterized by a brownish-grey silty clay surface soil to a depth of 8 inches and a mottled yellowish-brown and grey subsoil. To a depth of about 18 inches the subsoil is a heavy silty clay loam and below this a silty clay. The lower subsoil is heavy. The

natural drainage is poor and the soil very acid unless limed. The 2-acre area slopes slightly to the north and has good surface drainage, as indicated in Figure 2 A, B, and C. It has also been tiled.

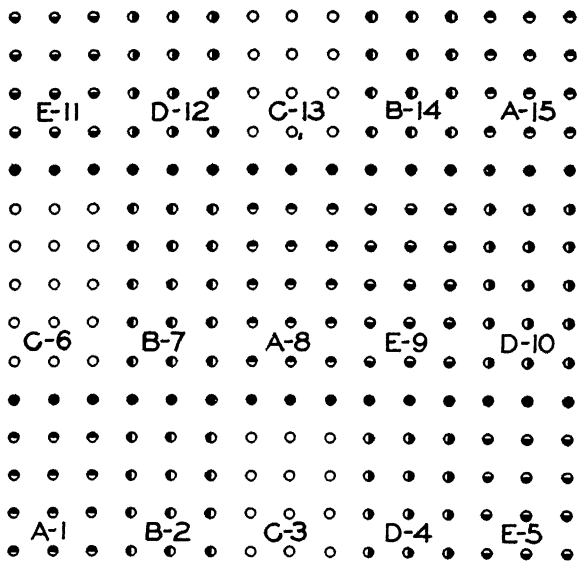

Fig. 1.—Plan of experimental plots in Soil Management Experiment. A-1, A-8, A-15—Cultivated with cover crop (plowed). B-2, B-7, B-14—Bluegrass sod with added nitrogen. C-3, C-6, C-13—Grass and straw mulch. D-4, D-10, D-12—Alfalfa sod to 1934. Now mulched. E-5, E-9, E-11—Cultivation with cover crop (disked).

The *moisture equivalent* of the soil is 25 per cent[2], and the *wilting percentage*, as determined by the use of young seedling sunflower plants, is 9.5 per cent.

TREATMENT OF SOIL PREVIOUS TO PLANTING

For many years the land now occupied by the orchard had been used for the production of general farm crops. Previous to planting the orchard, the land was plowed and well cultivated. Early in 1929 previous to planting lime was applied, at the rate of 4 tons per acre, and an 0-14-6 fertilizer, at the rate of 300 pounds per acre. The pH of the top soil was uniformly 5.8 after the addition of the lime; the soil is very well buffered.

PROCEDURE IN ESTABLISHING THE TREATMENTS

Cultivation with cover crop plots.—The experimental plots were cultivated until the midsummer of 1929 and then allowed to develop a weed cover. In

[2]The moisture equivalent was determined by Dr. Richard Bradfield.

1930 they were plowed or disked in accordance with the treatment desired and then seeded to oats and vetch, the E plots on June 24 and the A plots on August 8.

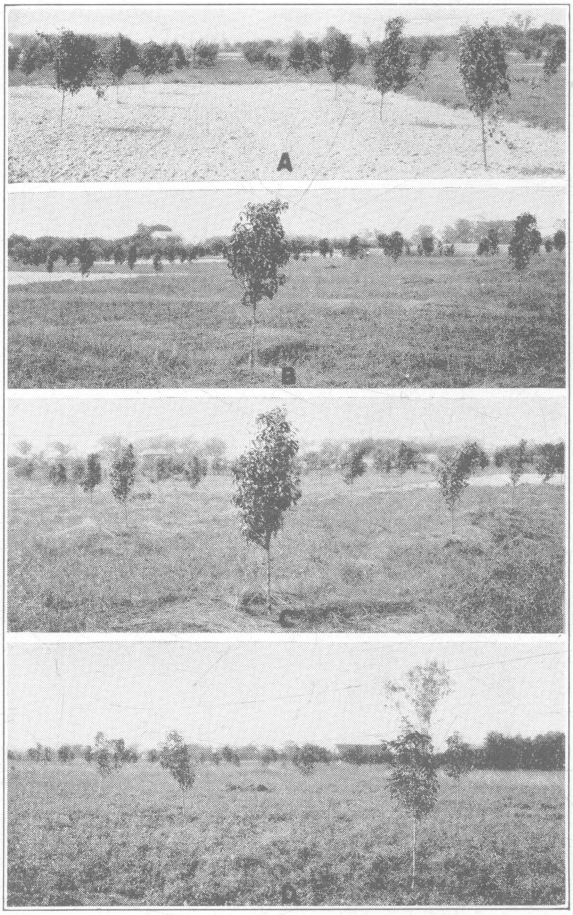

Fig. 2.—A. Trees in cultivated plot A-1 during first growing season of the experiment July 16, 1931. B. Trees in bluegrass with added nitrogen. Plot B-14, during first growing season of the experiment July 16, 1931. C. Trees in grass mulch plot C-6 during first growing season of experiment July 16, 1931. D. Trees in alfalfa plot D-4 during first growing season of the experiment July 16, 1931.

Kentucky bluegrass sod with nitrogen and grass mulch plots.—The bluegrass with nitrogen and the grass mulch plots were seeded in March, 1930 to the following mixture: Kentucky bluegrass, 12 pounds; red top, 6 pounds;

timothy, 6 pounds; and orchard grass, 4 pounds. This seeding produced fairly good results despite the dry year, and the plots were mowed three times. The mulch was first applied to the C plots on July 8, 1931, when a very heavy application was made. This, together with that added from a second cutting, killed all the grass beneath the trees during the summer of 1931.

Alfalfa sod.—The alfalfa plots were seeded with the Hardigan variety in 1929. A good growth resulted and the plots were mowed for the first time in June 1930.

The entire orchard received a second liming, at the rate of 2 tons per acre, and an application of 0-14-6 fertilizer, at the rate of 300 pounds per acre, in the spring of 1931. All the plots but the mulched ones were in place by the summer of 1930, but not all the treatments were established until the summer of 1931.

TREATMENT OF THE PLOTS DURING THE COURSE OF THE EXPERIMENT

Cultivation with cover crop (plowing)—A plots.—During the course of the experiment, the area occupied by these plots has been plowed in April as soon as the land could be worked and seeded to oats and vetch between July 1 and 10.

Kentucky bluegrass sod with nitrogen—B plots.—These plots have been fertilized throughout the course of the experiment with sodium nitrate, applied each year between April 11 and 24. The amount per tree was 1 pound from 1931 to 1933 and 2⅓ pounds in 1934 and in 1935.

Grass and straw mulch—C plots.—The grass has been cut and used as a mulch at least twice a year. In April 1934 additional mulch and 1½ pounds of sodium nitrate per tree were applied. Two hundred pounds of mulch per tree were applied in 1935. The radius of the mulched area is now 6 to 8 feet from the trunk of the tree.

Alfalfa sod—D plots.—The alfalfa plots have been mowed at least twice yearly (June and August). The yield of the first cutting yearly is given in Table 1. Beginning in 1934 the alfalfa was raked up and used as a mulch around the trees. By the end of 1935 the mulching materials were sufficient to kill a moderate proportion of the alfalfa beneath most of the trees in D-12 plots out as far as the drip of the branches. In the D-4 and D-10 plots the yield of alfalfa has been sufficient to destroy only a small proportion of the alfalfa beneath the drip of the branches.

TABLE 1.—Yield of First Cutting of Alfalfa in Alfalfa Plots, 1930-1932, 1934-1935

Year	Yield of air-dried alfalfa Tons per acre		
	Tier 1	Tier 2	Tier 3
1930	1.81	1.54	1.85
1931	3.57	3.30	2.67
1932	2.48	2.83	2.19
1934	2.65	2.44	2.71
1935	3.37	2.85	3.77

Cultivation with cover crop (disking)—E plots.—These plots were disked in early April, cultivated until early June, and then seeded to oats and vetch, usually during the first 3 weeks of June.

The trees of all plots were covered with cheesecloth bags from June 13 to July 10, 1931, to prevent injury from the 17-year locust. In the spring of 1932, 0-14-6 fertilizer was again applied over the entire area at the rate of 300 pounds per acre.

RAINFALL RECORD DURING YEARS OF EXPERIMENT

Table 2 presents the rainfall by months during the growing seasons from 1929 to 1935, inclusive. Unfortunately, due to factors beyond the writer's control, no rainfall records for Strongsville are available for 1933 and 1934. In consequence, the data for those years are taken from the records at Medina about 10 miles south (Patton, 16).

TABLE 2.—Rainfall by Months During Growing Season, Strongsville, 1929-1935

Year	April	May	June	July	Aug.	Sept.	Oct.	Growing season total	Yearly total
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1929	6.38	4.39	4.41	5.86	1.45	2.01	2.33	26.83	40.04
1930	2.36	1.48	3.05	1.97	1.77	2.29	1.41	14.33	29.41
1931	5.77	3.04	4.88	0.92	3.24	3.34	1.55	22.74	36.84
1932	2.57	3.98	2.01	4.30	2.08	1.32	3.28	19.54	36.56
1933*	3.44	2.89	2.52	1.48	1.16	2.52	1.04	15.05	25.80*
1934*	3.03	0.48	2.73	5.67	2.89	3.79	1.36	19.95	28.47*
1935	1.45	3.30	2.93	2.31	5.84	2.84	2.12	20.79	.....
Average 1897–1933	3.39	3.55	3.34	3.83	3.43	3.54	2.79	23.87	38.64

*Records taken at Medina (10 miles south).

Comparison of the rainfall per month with the average for the years 1897 to 1933 shows that, beginning with 1929, 36 out of the 49 months (April to October, inclusive) have had less than the average rainfall (Alexander and Patton, 1). Beginning with 1931, 26 months out of 35 (April to October) have had less than the average rainfall for the period. During 20 of these months the deficiency exceeded 0.5 inch. Six out of seven growing seasons since 1929 have shown less than the average total rainfall, the year 1929 being the only exception.

Taking the months of May, June, and July (1931 to 1935), when growth of terminal shoots and leaves is the greatest, 11 out of 15 months have received less than the average rainfall. During each year from 1 to 3 of these months have had deficient rainfall.

HYDROGEN-ION CONCENTRATION OF THE SOIL

The hydrogen-ion concentration of the plots in 1935 is given in Table 3. Since the pH value in 1930 was 5.8, it is evident that there has been an appreciable decrease in the hydrogen-ion concentration of the soil in the cultivated-disked plots, as well as in the grass plots. Two of the alfalfa plots, D-4 and D-12, had a pH of 6.25 and 6.04, respectively, but that of the D-10 plot was 5.47. Possibly this has been one reason why alfalfa has had to be reseeded in the D-10 plot in 1936.

TABLE 3.—Hydrogen-Ion Concentration of the Plots in the Various Treatments, Strongsville, September 1935

Treatment of plots	Hydrogen-ion concentration
	pH
Cultivation with cover crop (plowing)	5.68
Cultivation with cover crop (disking)	6.14
Grass and straw mulch	6.59
Bluegrass sod with nitrogen	6.59
Alfalfa sod	5.92

PRESENTATION OF THE DATA

The principal data taken during the course of the experiment have been: (a) circumference at base of trunk, (b) weight of prunings per tree, (c) total number and weight of fruits per tree, (d) soil moisture and nitrates in various plots, (e) percentage of flowers which developed into fruits after the June drop, (f) height and breadth of trees at the end of the experiment, and (g) yield of alfalfa in the alfalfa plots.

There were 39 trees in each plot of the original planting, but early in the life of the orchard it was found necessary to replace six trees injured by mowing and tillage implements. During the entire period no trees have been removed because of blight, which has been a minor hazard in this case. Blight was observed in only two trees, both in the cultivated area, early in 1935, and a moderate amount of growth was removed from these trees. They are still fully as large as any in the plot. An adjacent apple orchard was free from blight until 1936 and there is no pear planting within several hundred yards.

GROWTH OF THE TREES UNDER THE VARIOUS TREATMENTS

The area of the cross section of the trunk of each tree was calculated from the circumference measurement and the area of the previous year subtracted from this figure to show the yearly gain. In this manner the average yearly gain per tree has been determined for each plot. The gains for the years 1929 and 1930, the period during which the treatments were being established, are given in Table 4.

The growth per tree in each treatment was nearly the same during 1929, the year of planting. In 1930, in consequence of the very dry growing season, the trees in the grass plots (B and C) made considerably less growth than those in the cultivated plots. In the cultivated plots the average gain in cross-sectional area per tree ranged from 0.31 to 0.38 square inch, as compared to 0.21 for the trees in the grass plots. The trees in alfalfa made approximately half the growth of the trees in grass. As might have been predicted from these differences in cross-sectional area, the trees in the cultivated plots were larger on the average than those in any other treatment in the spring of 1931 although the trees in the grass plots were fully as uniform in size.

That moisture was the limiting factor in the growth of the trees in bluegrass sod and in alfalfa in 1930 is indicated by the low values for soil moisture in these plots on August 28 (Table 5) at the end of two very dry months (Table 2). The moisture content for the grass plots ranged from 10.3 to 10.7 per cent whereas that for the two alfalfa plots varied from 9.2 to 12.1 per cent.

These values, it is to be noted, are close to 9.5 per cent, the soil wilting percentage. This is indirect evidence supporting the conclusion that water was the factor limiting tree growth in the grass and alfalfa plots during 1930.

TABLE 4.—Average Gain per Tree in Area of Cross Section of Trunk During Establishment of Treatments, 1929-1930

	Plot	No. of trees	Average gain per tree in area of cross section of trunk		
			1929	1930	Total 1929-1930
			Sq. in.	*Sq. in.*	*Sq. in.*
Cultivation with cover crop (plowing)	A- 1	10	0.07	0.29	0.36
	A- 8	15	0.03	0.51	0.54
	A-15	12	0.08	0.33	0.41
	Average	....	0.06	0.38	0.43
Cultivation with cover crop (disking)	E- 5	12	0.04	0.28	0.32
	E- 9	14	0.03	0.36	0.39
	E-11	12	0.07	0.30	0.36
	Average	....	0.05	0.31	0.36
Grass mulch	C- 3	11	0.04	0.15	0.18
	C- 6	15	0.06	0.26	0.32
	C-13	12	0.07	0.21	0.28
	Average	....	0.06	0.21	0.26
Bluegrass sod with nitrogen	B- 2	12	0.06	0.19	0.25
	B- 7	15	0.06	0.27	0.33
	B-14	12	0.05	0.17	0.22
	Average	.....	0.06	0.21	0.26
Alfalfa sod	D- 4	11	0.02	0.07	0.10
	D-10	14	0.07	0.15	0.22
	D-12	12	0.05	0.11	0.16
	Average	.....	0.05	0.11	0.16

It was noted that the trees in the middle tier (Plots C-6 to D-10) made during 1930 greater growth than the trees in corresponding plots of the other two tiers (A-1 to E-5, E-11 to A-15). This difference in growth has continued up to the present, but the reasons for such variation among the tiers is not known. Nothing of the previous history of the soil gives a clue to an explanation.

TABLE 5.—Soil Moisture and Nitrates in Various Treatments, August 28, 1930

Treatment	Plot	Moisture*	Nitrates†
		Pct.	*P.p.m.*
Cultivation with cover crop (plowing)	A-1	20.3	49.70
	A-8	19.3	61.60
Cultivation with cover crop (disking)	E-5	13.4	27.45
Bluegrass sod with nitrogen	B-2	10.3	29.58
Grass mulch	C-3	10.7	16.98
Alfalfa sod	D-4	9.2	13.48
	D-10	12.1	11.72

*Moisture expressed on dry soil basis.
†Nitrates calculated on wet soil basis.

GROWTH OF THE TREES DURING FIRST YEAR OF EXPERIMENT (1931)

The average gain per tree in cross-sectional area of the trunk in the cultivated plots was greater than that of the trees in any other treatment (Table 6). The values for the cultivated-plowed and cultivated-disked plots were 0.76 and 0.54 square inch, respectively, as compared with 0.44 square inch for the trees in grass mulch. The trees in bluegrass sod showed a gain of 0.37 square inch; whereas those in alfalfa increased only 0.28 square inch. Representing the gain in the cultivated-plowed plots as 100, the gain in the cultivated-disked plot was 71, in mulch 58, in bluegrass sod 49, and in alfalfa 37. The mulched plot, C-6, in the middle tier made a growth equal to that of the cultivated-disked plot, E-9, but the smaller growth of the trees in the two remaining mulched plots reduced the average gain of the treatment to a point lower than that for the cultivated treatments. That the differences between the mulched and the bluegrass sod treatments were no greater is due to the fact that the trees in the C plots were first mulched in early July after a considerable proportion of the growing season had elapsed.

TABLE 6.—Average Gain per Tree in Area of Cross Section of Trunk During Period of Experiment, 1931-1935

	Plot	No. of trees	Average gain per tree in area of cross section of trunk					
			1931	1932	1933	1934	1935	Total 1931–1935
			Sq. in.	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*
Cultivation with cover crop (plowing)	A- 1	10	0.74	0.95	0.91	1.29	1.44	5.33
	A- 8	15	0.90	1.36	1.02	1.41	1.88	6.57
	A-15	12	0.64	1.12	1.12	1.38	1.31	5.57
	Average	... .	0.76	1.14	1.02	1.36	1.54	5.82
Cultivation with cover crop (disking)	E- 5	12	0.48	0.78	0.75	1.06	1.12	4.19
	E- 9	14	0.54	1.14	1.21	1.90	2.42	7.21
	E-11	12	0.59	0.96	1.12	1.37	1.49	5.53
	Average	.....	0.54	0.96	1.03	1.44	1.68	5.64
Grass and straw mulch	C- 3	11	0.44	0.98	0.84	1.42	1.99	5.67
	C- 6	15	0.53	1.02	0.83	1.53	1.87	5.78
	C-13	12	0.35	0.86	0.81	1.26	1.49	4.77
	Average	.....	0.44	0.95	0.83	1.40	1.78	5.41
Bluegrass sod with nitrogen	B- 2	12	0.34	0.47	0.51	0.83	1.08	3.23
	B- 7	15	0.43	0.61	0.83	0.99	1.25	4.11
	B-14	12	0.33	0.40	0.61	0.70	0.75	2.79
	Average	.....	0.37	0.49	0.65	0.84	1.03	3.37
Alfalfa sod	D- 4	11	0.26	0.38	0.42	0.79	0.97	2.82
	D-10	14	0.33	0.47	0.38	0.83	1.07	3.08
	D-12	12	0.24	0.28	0.31	0.67	0.86	2.36
	Average	.....	0.28	0.34	0.37	0.76	0.97	2.75

The moisture content of soil samples taken during May and June, months in which rainfall was nearly normal, was quite satisfactory and showed no significant differences (Table 7). However, July, as indicated by Table 2, had the lowest rainfall of any month but one during the course of the experiments. Unfortunately, soil samples were not taken during this period when very pro-

nounced differences in soil moisture between plots in the various treatments were observed. The alfalfa plots had produced high yields (Table 1), and the grass in the bluegrass sod with added nitrogen grew luxuriantly. As a consequence, during July and August the soil moisture under the trees in the alfalfa and bluegrass sod was much lower than that under the mulched trees. In September, as indicated by the data in Table 7, the soil moisture under the trees in grass mulch was much higher than in any other treatment, but it is not believed that the soil moisture in the bluegrass sod and alfalfa plots was still at the critical point. The rainfall during late August and early September had been sufficient to raise the soil moisture in these plots to values comparable to those found in the soil of the cultivated plots.

The nitrate content of the soil is also presented in Table 7. During May and June the nitrates were higher under the trees in the bluegrass sod with nitrogen added than under the trees of any other treatment; whereas in September the cultivated plots possessed a higher average content. Since the soil nitrates were not limiting at any time, it is evident that there was no correlation of nitrate content with growth of the trees.

GROWTH OF THE TREES DURING 1932

The trees in the cultivated-plowed plots made a greater gain in cross-sectional area in 1932 than the trees in the cultivated-disked and mulched plots, whose growth was the same (Table 6). The trees in bluegrass sod made only half the gain (0.49 square inch) of the trees in the cultivated-disked and mulched plots; whereas the trees in alfalfa sod made the poorest growth with a gain of 0.34 square inch per tree, which was only 36 per cent of that of the trees in these plots. Representing the gain in the cultivated-plowed plots as 100, the gain in the cultivated-disked and mulched plots was 83, in bluegrass sod 43, and in alfalfa 30.

As indicated by Table 7, the soil of the various plots started the season with a very satisfactory moisture content, but, as a result of the low rainfall during late May and early June, by June 8 the soil moisture was considerably reduced under the trees in the bluegrass sod and alfalfa plots. In the grass mulch plots the soil moisture averaged 20.6 per cent; whereas the bluegrass sod and alfalfa plots averaged 12.2 and 13.2 per cent, respectively. The soil in the cultivated plots was 15.0 per cent (Table 7). Furthermore, despite the fact that the rainfall was average for July, the soil moisture content on August 1 was still lower than on June 8 in the bluegrass sod and the alfalfa plots. Three of the six plots involved had a soil moisture content ranging from 8.1 to 9.8 per cent, which closely approximated the wilting percentage (9.5). Two other plots had moisture contents of 10.5 and 11.0 per cent while the remaining one had 14.3 per cent. On the other hand, the average soil moisture under the trees in mulch was 22.4 per cent, which was considerably higher even than that under the cultivated trees. In fact, the soil moisture content in the cultivated-disked plots was nearly as low as under the trees in the bluegrass sod.

As opposed to the soil moisture situation, the nitrate content of the soil in the bluegrass sod plots was very high throughout the growing season. Furthermore, the nitrate content, although very much lower under the trees in alfalfa, was still equal to that in the grass mulch and the cultivated-disked plots. The nitrate content of the soil in the cultivated-plowed plots was some-

what higher than that in the cultivated-disked plots but was much lower than that in the bluegrass sod plots. It was again evident that there was no positive correlation between nitrates in the soil and the growth of the trees.

TABLE 7.—Soil Moisture and Nitrates in Plots of Various Treatments,* 1931-1932

Treatment	Plot	Moisture† Percentage			Nitrates‡ Parts per million		
		1931			1931		
		May 15	June 29	Sept. 17	May 15	June 29	Sept. 17
Cultivation with cover crop (plowing)	A- 1	19.8	13.6	12.2	17.8	14.3	28.7
	A- 8	21.9	14.8	14.3	9.1	7.3	17.8
	A-15	18.6	13.0	13.0	14.3	0.7	37.8
	Average	20.0	13.6	13.0	13.7	7.4	28.1
Cultivation with cover crop (disking)	E-5	19.8	15.6	14.3	9.1	7.3	17.5
Grass mulch	C-3	20.0	18.4	24.4	6.3	3.8	10.8
	C-6	19.8	15.6	21.2	5.6	2.1	7.7
	Average	19.8	17.0	22.1	5.9	2.9	9.2
Blue grass sod with nitrogen	B-2	20.3	18.4	14.3	26.6	3.8	16.1
	B-7	18.4	17.0	14.6	17.8	25.5	14.3
	Average	19.5	17.7	14.5	22.2	14.6	15.2
Alfalfa sod	D- 4	21.2	17.7	15.6	6.3	3.8	9.1
	D-10	17.7	18.9	14.8	33.6	3.8	10.8
	Average	19.5	18.2	15.2	20.4	3.8	9.9
		1932			1932		
		May 20	June 8	Aug. 1	May 20	June 8	Aug. 1
Cultivation with cover crop (plowing)	A-1	21.8	15.6	13.5	14.0	10.8	11.6
	A-8	17.4	14.5	17.7	12.6	14.9	16.1
	Average	19.5	15.0	15.5	13.3	12.8	13.8
Cultivation with cover crop (disking)	E-5	17.7	.....	11.3	10.5	.....	7.4
	E-9	24.2	.....	14.3	7.7	.....	9.8
	Average	20.6	.....	12.7	9.1	.....	8.6
Grass mulch	C- 3	19.8	.....	24.2	7.3	.....	7.0
	C- 6	26.4	21.7	24.2	8.7	9.1	8.8
	C-13	26.0	19.7	18.9	5.6	7.3	10.8
	Average	24.2	20.6	22.4	7.2	8.2	8.8
Bluegrass sod with nitrogen	B- 2	24.2	12.2	11.0	40.6	58.1	15.8
	B- 7	21.2	12.0	14.3	54.6	45.8	12.6
	B-14	16.8	.....	9.3	54.6	.....	14.4
	Average	20.5	12.2	11.5	49.9	51.9	14.2
Alfalfa sod	D- 4	23.0	.....	9.8	12.2	.....	5.6
	D-10	22.7	12.2	10.5	7.3	5.6	10.8
	D-12	16.6	14.3	8.1	5.6	7.3	5.6
	Average	20.5	13.2	9.4	7.9	6.4	7.3

*These and subsequent soil moisture and nitrate determinations were carried out by the Department of Agronomy under the direction of Dr. V. H. Morris.

†Moisture expressed in per cent on dry soil basis.

‡Nitrates calculated on wet soil basis.

GROWTH OF THE TREES DURING 1933

During 1933 the trees in the cultivated plots averaged a gain of 1.02 square inches per tree; whereas that for the mulched trees was 0.83 square inch (Table 6). The corresponding gains for the trees in the bluegrass sod and alfalfa plots were 0.65 and 0.37 square inch, respectively. Representing the gain in the cultivated plots as 100, the gain in the mulched plots was 81, in bluegrass sod 64, and in alfalfa 36.

As indicated by the data in Table 2, the rainfall was below average from May to October, 1933. Unfortunately, no soil samples could be taken during 1933, but it was observed that the soil moisture content throughout the season was much less in the bluegrass sod and alfalfa plots than in those of any other treatment. In 1933 it became evident that mulching material in addition to that produced between the trees would be required if the grass were to be killed at a reasonable distance beyond the drip of the branches. It was also noted at this time that the Buffalo tree hopper had injured a considerable number of the trees in the alfalfa plots but only a few of the trees in the adjacent rows of the bluegrass sod and cultivated plots.

GROWTH OF THE TREES DURING 1934

In 1934 growth of the trees in the cultivated and mulched plots was practically the same (Table 6). The gains in cross-sectional area per tree were considerably greater for all treatments than in 1933, averaging 1.44, 1.40, and 1.36 square inches, respectively, for the cultivated-disked, mulched, and cultivated-plowed plots. On the other hand, the gain of the trees in bluegrass sod was 0.84 square inch; whereas that for the trees in alfalfa was 0.76 square inch, a value double that made by the same trees in 1933. On the basis of 100 as the average gain for the trees in the cultivated and mulched plots, those for the bluegrass sod and alfalfa plots were 60 and 54, respectively.

The rainfall for April was only slightly less than average, but on May 1 the moisture content of the soil in the mulch plots averaged 27.9 per cent, as compared to 19.5, 17.7, and 16.3 per cent for the cultivated, bluegrass sod, and alfalfa plots, respectively. During May and June the rainfall was much below average, with May showing the lowest precipitation of any month of any growing season during the experiments (Table 2). In consequence, the soil moisture on June 1 showed 9.5 per cent in one bluegrass sod plot and 13.2 per cent in another. Two alfalfa plots showed 11.2 and 11.4 per cent moisture. On the other hand, the soil moisture averaged 20.7 and 17.3 per cent under the mulched and cultivated plots, respectively. The July rainfall was somewhat above the average, but August was very deficient and by August 25 the soil moisture content in the bluegrass sod and alfalfa plots was reduced to the low values shown on June 1. By this time the soil moisture content under the mulched and cultivated trees had fallen to an average of 15.6 and 12.6 per cent, respectively.

During May and June the soil under the bluegrass sod, due to the nitrates applied, showed the highest content of any treatment. Again the differences between the soil nitrate content in the various treatments showed no relationship to differences in growth of the trees.

During 1934 the alfalfa grown on the various plots was raked up and used as a mulch around the trees. In consequence, by the end of the year a moderate proportion of the growing alfalfa beneath the drip of the branches was

killed out, but still the greater proportion of the trees' roots was undoubtedly in competition for water with the roots of the alfalfa. It was evident that even more material would be required in these plots if the trees were to be thoroughly mulched.

GROWTH OF THE TREES DURING 1935

During 1935 the trees in the mulched plots made a slightly greater gain in cross-sectional area than the trees in the cultivated-plowed plots but not significantly different from that of the trees in the cultivated-disked plots (Table 6). The values for the mulched, cultivated-disked, and cultivated-plowed plots were 1.78, 1.68, and 1.54 square inches, respectively. Again, for the second year, the trees in alfalfa made nearly the same gain as the trees in the bluegrass sod; namely, 0.97 square inch as compared with 1.03. These two values represented less than 60 per cent of the growth made by the trees in the cultivated-disked and mulched treatments. Representing the gain in the mulched plots as 100, the gain in the cultivated-disked plot was 94, in the cultivated-plowed 87, in bluegrass sod 58, and in alfalfa 55. Comparison of the gains in cross-sectional area made in 1935 with those in 1934 shows that in all but one plot the values were higher than in the corresponding plots in 1934.

The rainfall in April (Table 2) was very deficient but that of May was nearly normal. On May 9 the moisture content of the soil was high in all plots (Table 8). June was somewhat deficient in rainfall but was higher than that of any other June but one during the 5-year period. On June 13 the soil moisture content was still high under the mulched plots but was considerably reduced in the plots of the other treatments. July was also somewhat deficient in rainfall, and on July 15 the moisture content of all plots was reduced still further. In one plot of the bluegrass sod, B-14, the soil moisture was only 10.7 per cent. August was a very wet month, and in consequence on September 16 the moisture content of all plots had risen to percentages somewhat similar to those present on June 13.

The nitrate content of the soil, as shown in Table 8, was high in all plots throughout the year, but the amount present in the bluegrass sod plot was particularly high at the beginning of the growing season.

TOTAL GROWTH OF THE TREES DURING THE 5-YEAR PERIOD

Table 6 also presents the average total gain in cross-sectional area per tree in each plot during the 5-year period of the experiments. The total gains of the trees in the cultivated-plowed, cultivated-disked, and mulched treatments were 5.82, 5.64, and 5.41 square inches, respectively. Since the growth of the mulched trees was only 7 per cent less than that for trees in the cultivated-plowed plots, the difference is not considered significant. On the other hand, the trees in the bluegrass sod showed a gain of 3.37 square inches, while that of the trees in alfalfa was only 2.75 square inches. Representing the gain of the trees in the cultivated-plowed plots as 100, the gain in the cultivated-disked plots was 97, in mulch 93, in bluegrass sod 58, and in alfalfa 47.

Examination of the data in Table 6 clearly shows, as had already been pointed out, that the trees in the plots of the middle tier consistently showed a

greater growth than the trees in the corresponding plots of the other two tiers. In view of this fact, comparisons become more apparent if noted among the different treatments but within the same tier.

TABLE 8.—Soil Moisture and Nitrates in Plots of Various Treatments, 1934-1935

Treatment	Plot	Moisture* Percentage			Nitrates† Parts per million		
		1934			1934		
		May 1	June 1	Aug. 25	May 1	June 1	Aug. 25
Cultivation with cover crop (plowing)	A-1	17.7	16.7	10.9	17.68	15.00	38.36
	A-8	21.2	18.0	14.6	24.02	23.60	34.10
	Average	19.5	17.3	12.6	20.85	19.30	36.23
Grass and straw mulch	C- 6	29.4	21.2	19.5	18.60	14.72	18.98
	C-13	26.3	20.4	12.2	22.86	17.00	19.76
	Average	27.9	20.7	15.6	20.73	15.86	19.37
Bluegrass sod with nitrogen	B- 2	18.5	13.2	15.2	19.18	35.40	20.15
	B-14	16.6	9.5	7.9	51.15	17.00	18.13
	Average	17.7	11.5	11.5	35.16	26.20	19.14
Alfalfa sod	D-10	16.0	11.2	15.1	13.56	16.27	24.41
	D-12	16.7	11.4	9.7	17.63	13.56	22.86
	Average	16.3	11.3	12.2	15.54	14.91	23.63
		1935			1935		
		May 9	June 13	July 15	Sept. 6	May 9	June 13	July 15	Sept. 6
Cultivation with cover crop (plowing)	A- 1	23.3	18.2	16.0	15.9	34.30	18.20	26.25	13.30
	A- 8	..	18.6	17.7	17.8	....	14.00	24.33	14.70
	A-15	21.7	16.4	14.5	16.3	46.20	11.55	27.30	11.55
	Average	22.5	17.7	15.7	16.7	40.25	14.58	25.96	13.18
Cultivation with cover crop (disking)	E- 5	24.2	19.4	17.1	19.8	44.45	17.15	16.80	19.25
	E- 9	....	22.0	18.5	20.0	.....	14.35	16.63	19.77
	E-11	23.4	18.0	13.5	16.0	52.15	15.40	30.80	15.75
	Average	23.8	19.8	16.3	18.6	48.29	15.63	21.41	18.26
Grass and straw mulch	C- 3	30.8	26.4	22.7	25.0	50.05	24.15	15.40	14.70
	C- 6	25.8	27.0	21.6	22.8	....	23.80	20.30	19.25
	C-13	28.3	26.3	17.3	20.7	65.80	25.90	13.65	33.25
	Average	28.3	26.6	20.5	22.8	57.93	24.62	16.45	22.40
Bluegrass sod with nitrogen	B- 2	27.2	19.4	15.3	19.7	66.85	26.95	33.78	11.20
	B- 7	....	19.7	16.6	19.9	.....	13.65	18.20	8.57
	B-14	22.4	13.5	10.9	15.3	60.55	25.20	22.05	13.30
	Average	24.8	17.5	14.3	18.3	63.70	21.93	24.68	11.02
Alfalfa sod	D- 4	25.8	18.5	14.2	19.5	50.22	16.10	13.65	21.70
	D-10	....	18.7	15.8	21.8	.....	14.35	17.15	16.80
	D-12	25.9	17.8	12.5	17.1	51.45	13.65	15.75	25.90
	Average	25.8	18.3	14.2	19.5	33.89	14.70	15.52	21.47

*Moisture expressed in per cent on dry soil basis.
†Nitrates calculated on wet soil basis.

TRUNK CIRCUMFERENCE, WIDTH OF HEAD, AND HEIGHT OF TREES AFTER THE 5-YEAR PERIOD

The data in Table 9 show the average trunk circumference, width of head, and height per tree at the end of the 5-year period, March 1936. As would be predicted from the data for gain in area of cross section of the trunk, there was no significant difference in the average circumference per tree in the cultivated-plowed, cultivated-disked, and mulched treatments, the values being 8.99, 8.75, and 8.70 inches, respectively. The trees in the bluegrass sod averaged 6.98 inches in circumference, or 80 per cent of the trees in mulch; whereas those in alfalfa averaged 6.36 inches, or 73 per cent of the trees in mulch.

Figure 3 is a frequency curve of the trunk circumference of the trees in the cultivated and mulched plots. It is to be noted that the trees in the mulched plots were more uniform in size than those in the cultivated plots. The range in circumference of the trees in the cultivated plots was from slightly above 5 to nearly 12 inches but was only from 7.5 to 10.75 inches with the trees in the mulched plots.

TABLE 9.—Average Trunk Circumference, Width, and Height per Tree at End of 5-year Period, March 1936

Treatment	Plot	No. of trees	Trunk circumference	Width of head	Tree height
			In.	*Ft.*	*Ft.*
Cultivation with cover crop (plowing)	A- 1	10	8.60	6.33	9.55
	A- 8	15	9.54	7.12	11.00
	A-15	12	8.82	5.92	9.92
	Average	.....	8.99	6.46	10.16
Cultivation with cover crop (disking)	E- 5	12	7.68	5.77	9.16
	E- 9	14	9.78	7.37	11.97
	E-11	12	8.79	5.96	9.75
	Average	.....	8.75	6.37	10.29
Grass and straw mulch	C- 3	11	8.86	6.70	12.23
	C- 6	15	9.00	7.12	11.30
	C-13	12	8.24	6.60	10.58
	Average	.....	8.70	6.81	11.37
Bluegrass sod with nitrogen	B- 2	12	6.95	4.35	9.25
	B- 7	15	7.53	5.23	9.83
	B-14	12	6.46	3.92	8.30
	Average	.....	6.98	4.50	9.13
Alfalfa sod	D- 4	11	6.38	4.61	8.41
	D-10	14	6.73	4.98	8.93
	D-12	12	5.98	4.00	7.67
	Average	.....	6.36	4.53	8.34

The width of the head of the trees was also similar for the trees of the cultivated-plowed, cultivated-disked, and mulched treatments, being 6.46, 6.37, and 6.81 feet, respectively, for these treatments (Table 9). On the other hand, the trees in bluegrass sod with nitrogen and in alfalfa had the same average width of head; namely, 4.53 feet, a value 67 per cent of that of the trees in mulch.

The trees in mulch averaged a height of 11.37 feet per tree, slightly over 10 per cent greater than that of the trees in the cultivated-plowed and cultivated-disked treatments. On the other hand, the trees in bluegrass sod aver-

aged 9.13 feet, or 81 per cent of that of the trees in mulch; whereas the trees in alfalfa had an average height of 8.34 feet, or 74 per cent of that of the trees in mulch.

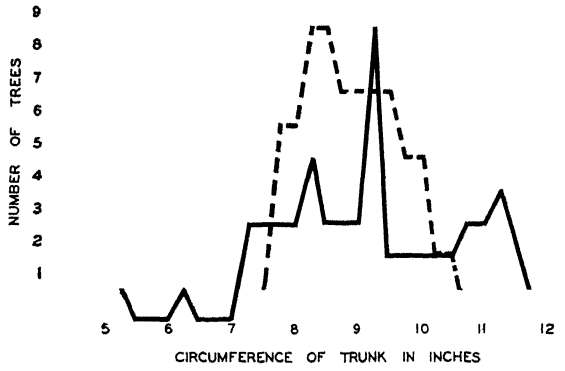

Fig. 3.—Frequency curve of trunk circumference of trees in cultivated and mulched plots. Broken line—Trees in the mulched plots. Solid line—Trees in the cultivated plots.

WEIGHT OF PRUNINGS REMOVED AND THEIR RELATION TO TREE GROWTH

The weight of prunings removed annually is given in Table 10. Examination of the weights removed during each of the 5 years shows several interesting facts. A greater amount was removed per tree from the cultivated plots than from the mulched plots until 1936, when the weights from the cultivated-plowed and mulched plots were fairly similar. From 1932 to 1935 the prunings removed annually from the trees in bluegrass sod were only about one-third and in 1936 about one-sixth of the weight removed from the mulched trees. The prunings from the trees in alfalfa were consistently less than the amounts removed from the trees in bluegrass sod. At the end of the 5-year period approximately 3.4 pounds (53 to 54 ounces) had been removed per tree in the cultivated treatments. On the other hand, the total amount removed per tree from the mulched plots was 2.6 pounds (41 ounces); whereas the prunings taken from the trees in bluegrass sod and in alfalfa were 10 ounces and 6 ounces per tree, respectively.

In order to represent the relationship between prunings removed and tree growth, there is presented in Table 11 the weight of prunings per gain of 1 square inch in the cross-sectional area of the trunk. It is to be noted that annually since 1931 a greater weight of prunings was removed on this basis from the cultivated than from the mulched trees, a fact which is reflected in the total amount removed for the 5-year period. At the end of this period approximately 40 to 41 ounces from the cultivated trees, as compared to 29.8 ounces from the mulched trees, had been removed per gain of 1 square inch. The comparable weight which was removed from the trees in bluegrass sod was 12.2 ounces; whereas the corresponding value for the trees in alfalfa was 8.8 ounces. It is to be recalled that the trees in the cultivated and mulched plots showed no significant difference in the gain in cross-sectional area at the

end of the 5-year period. The fact that relatively a smaller amount of prunings was removed from the trees in mulch than from the trees in cultivation would seem to indicate that the former trees contained less undesirable wood than the trees in the cultivated plots. On the other hand, the weight of prunings removed from the trees in bluegrass sod was only 23 per cent of the weight removed from the trees in mulch. Similarly, the trees in alfalfa which had made only half the gain in cross-sectional area of the trees in mulch showed only a small fraction of the amount of pruning. This situation with the trees in bluegrass sod and in alfalfa indicates that, with a poorer growth of tree, a smaller proportion of the wood had to be removed in pruning. In general, this is to be expected, since as growth increased and the trees became thicker, a greater proportion had necessarily to be removed by pruning in order to prevent undesirable crossing and rubbing, as well as injury to the permanent framework of the trees.

TABLE 10.—Average Weight of Prunings per Tree in Plots of Various Treatments, 1932-1936

Treatment	Plot	No. of trees	Average weight of prunings removed per tree					
			1932*	1933	1934	1935	1936	Total 1932-1936
			Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*
Cultivation with cover crop (plowing)	A- 1	10	1.33	1.94	12.82	15.03	28.61	59.73
	A- 8	15	1.79	3.73	11.19	18.55	25.89	61.15
	A-15	12	0.22	1.76	8.32	11.45	19.58	41.33
	Average	.....	1.11	2.48	10.78	15.01	24.69	54.07
Cultivation with cover crop (disking)	E- 5	12	0.60	1.37	4.82	13.19	8.72	28.70
	E- 9	14	1.53	2.94	19.11	39.51	26.60	89.69
	E-11	12	0.61	0.80	7.66	11.72	20.38	41.17
	Average	.....	0.91	1.70	11.47	21.47	18.57	53.19
Grass and straw mulch	C- 3	11	0.22	2.21	4.44	15.11	31.10	53.08
	C- 6	15	0.45	1.76	7.25	11.83	22.91	44.20
	C-13	12	0.32	0.29	4.33	7.66	15.10	27.18
	Average	.....	0.33	1.42	5.34	11.33	23.06	41.49
Bluegrass sod with nitrogen	B- 2	12	0.06	0.50	0.75	3.06	4.53	8.90
	B- 7	15	0.30	0.84	2.33	5.33	4.69	13.49
	B-14	12	0.03	0.06	1.66	2.39	2.13	6.27
	Average	.....	0.13	0.47	1.58	3.59	3.78	9.55
Alfalfa sod	D- 4	11	0.11	0.70	0.72	2.75	4.15	8.43
	D-10	14	0.25	0.43	0.64	1.82	2.51	5.65
	D-12	12	0.00	0.00	1.00	0.92	1.73	3.65
	Average	.....	0.12	0.38	0.79	1.83	2.80	5.91

*Pruning was carried out in March from 1932 to 1936.

Finally, it is important to note that, in reality, a relatively small amount of prunings had been removed from the trees in the cultivated and mulched plots. By 1936, at the end of the 5-year period, about 3.4 pounds (53 to 54 ounces) had been removed per tree from the cultivated trees. This type of pruning unquestionably represented a very light amount.

TABLE 11.—Weight of Prunings Removed in Relation to Gain of 1 Square Inch in Cross-sectional Area per Trunk, 1931-1935

Treatment	Plots	Weight removed per 1 square inch gain in cross-sectional area					
		1931*	1932	1933	1934	1935	Total 1931-1935
		Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*
Cultivation with cover crop (plowing)	A	1.5	2.2	10.5	11.6	15.6	41.4
Cultivation with cover crop (disking).....	E	1.8	1.8	9.9	15.3	11.2	40.0
Grass and straw mulch	C	0.8	1.5	6.7	8.0	12.8	29.8
Bluegrass sod with nitrogen	B	0.4	1.0	2.7	4.4	3.7	12.2
Alfalfa sod	D	0.5	1.0	2.1	2.4	2.8	8.8

*Year of growth since prunings were removed during each subsequent March.

PERCENTAGE OF FLOWERS SETTING FRUIT

The percentage of flowers which had developed into fruits after the June drop is presented in Table 12. In 1932, in all but three plots the set ranged narrowly between 4.5 and 8.3 per cent. Of these three variable plots, two were in alfalfa and one in bluegrass sod. With these exceptions, the differences in fruit setting can hardly be considered of significance, although the fact that, in general, the alfalfa sod was conducive to somewhat poorer fruit set was also borne out by observation.

In 1933 the trees in the cultivated plots produced the greatest flowering; whereas the trees in the mulched plots were now next in flower production. Due to lack of sufficient cross pollination, the percentage of flowers setting fruit was low, ranging from 0.04 to 0.90 per cent.

In 1934 the percentage of flowers setting fruit ranged from 6.3 to 11.6 and the difference between treatments is not considered particularly significant.

YIELD OF FRUIT IN RELATION TO THE SOIL MANAGEMENT SYSTEM

The trees bore their first flowers in 1932, the fourth growing season from planting. The bloom was very light in all plots with only a few flowers to a tree. The trees in the cultivated plots bore the most flowers, with those in bluegrass sod and in mulch following in the order named. As indicated by the data in Table 13 the number of fruits produced was correspondingly small. The weight of fruits is shown in Table 14. The average weight of a fruit from the mulched trees was larger than from the cultivated trees, a result which might have been predicted because of the smaller number per tree. However, it is to be noted that the fruits on the trees in bluegrass sod, although fewer in number than those on the trees in cultivation, were of considerably less weight. Moreover, the few fruits produced on the trees in alfalfa weighed less per fruit than those from any other treatment.

In 1933, the bloom was quite satisfactory on all trees, and again the trees in cultivation produced the largest number of flowers. The flowering of the trees in grass mulch was appreciably greater than that of the trees in bluegrass sod and more than compensated for the smaller amount of bloom the previous year. Due to the writer's absence no pollinizing bouquets were introduced into the planting to take the place of the pollinizing trees which had not yet borne flowers. In consequence, the low yields obtained (Table 13) are the result of

TABLE 12.—Percentage of Flowers which Developed into Fruits after the June Drop, 1932-1934

Treatment	Plot	No. of trees	1932			1933			1934		
			Clusters	Fruits	Percentage	Clusters	Fruits	Percentage	Clusters	Fruits	Percentage
			No.	*No.*		*No.*	*No.*		*No.*	*No.*	
Cultivation with cover crop (plowing)	A- 1	10	157	47	4.60	1118	40	0.55	654	374	9.34
	A- 8	15	176	64	5.60	3056	93	0.47	1058	572	8.32
	A-15	12	70	21	4.62	944	25	0.41	512	256	7.69
	Average	.....	.....	.....	4.94	.....	.....	0.48	.....	.....	8.45
Cultivation with cover crop (disking)	E- 5	12	174	61	5.39	1130	66	0.90	610	386	9.74
	E- 9	14	66	22	5.13	1332	37	0.44	702	527	11.55
	E-11	12	176	95	8.30	1691	77	0.70	548	319	8.96
	Average	.....	.....	.....	6.27	.....	.....	0.68	.....	.....	10.08
Grass and straw mulch.....	C- 3	11	12	5	6.67	494	8	0.25	474	353	11.46
	C- 6	15	20	6	4.61	807	23	0.43	809	475	9.03
	C-13	12	31	9	4.47	815	21	0.40	361	249	10.61
	Average	.....	....	.....	5.25	....	.....	0.36	.....	....	10.37
Bluegrass sod with nitrogen	B- 2	12	102	34	5.13	403	20	0.76	425	179	6.48
	B- 7	15	68	20	4.52	522	7	0.21	460	241	8.06
	B-14	12	261	35	2.06	130	1	0.12	476	220	7.11
	Average	.....	.....	.....	3.90	.....	.....	0.36	.. ..	.....	7.22
Alfalfa sod	D- 4	11	8	0	0.00	253	10	0.61	498	204	6.30
	D-10	14	209	3	0.22	405	1	0.04	223	122	8.42
	D-12	12	58	19	5.04	228	5	0.34	297	123	6.37
	Average	.....	....	.....	1.75	.....	.....	0.33	....	....	7.03

TABLE 13.—Average Number and Weight of Pears per Tree in Plots of Various Treatments, 1932-1935

Treatment	Plot	No. of trees	1932		1933		1934		1935		Total	
			Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
				Lb.		*Lb.*		*Lb.*		*Lb.*		*Lb.*
Cultivation with cover crop (plowing)	A- 1	10	4.4	1.28	3.5	1.00	74.7	17.36	91.6	26.92	174.2	46.56
	A- 8	15	4.3	1.43	5.9	1.56	115.3	27.01	51.8	15.64	177.3	45.64
	A-15	12	1.8	0.68	1.9	0.58	68.4	14.41	102.3	27.31	174.3	42.97
	Average		3.5	1.13	3.8	1.05	86.1	19.59	81.9	23.29	175.3	45.06
Cultivation with cover crop (disking)	E- 5	12	4.8	1.16	5.2	1.33	48.5	11.19	77.7	22.28	136.2	35.97
	E- 9	14	1.5	0.56	2.2	0.64	76.9	22.16	106.1	30.26	186.7	53.62
	E-11	12	7.8	2.95	6.0	1.73	82.8	17.83	79.8	22.20	176.4	44.70
	Average		4.7	1.56	4.5	1.23	69.4	17.06	87.9	24.91	166.4	44.76
Grass and straw mulch	C- 3	11	0.5	0.17	0.6	0.15	37.5	10.52	74.8	23.95	113.5	34.79
	C- 6	15	0.3	0.11	1.4	0.31	63.5	18.19	91.9	28.83	157.2	47.45
	C-13	12	0.8	0.28	1.7	0.38	49.5	13.06	119.9	33.33	171.8	47.03
	Average		0.5	0.19	1.2	0.28	50.2	13.92	95.5	28.70	147.5	43.09
Bluegrass sod with nitrogen	B- 2	12	2.5	0.60	1.3	0.34	26.8	6.06	25.9	8.49	56.5	15.49
	B- 7	15	1.0	0.33	0.3	0.06	32.8	8.14	45.6	14.03	79.7	22.57
	B-14	12	2.6	0.78	0.0	0.00	27.0	5.29	16.3	4.86	45.9	10.93
	Average		2.0	0.57	0.5	0.13	28.9	6.49	29.3	9.13	59.7	16.33
Alfalfa sod	D- 4	11	0.0	0.00	0.7	0.14	19.6	4.26	64.8	18.25	85.2	22.65
	D-10	14	0.1	0.02	0.1	0.01	13.7	2.97	69.0	18.29	82.2	21.29
	D-12	12	1.3	0.25	0.2	0.01	14.5	2.53	66.9	16.66	82.8	19.45
	Average		0.5	0.09	0.3	0.05	15.9	3.25	66.9	17.73	83.4	21.13

TABLE 14.—Average Weight of Pear Fruits, 1932-1935

Treatment	Plot	1932	1933	1934	1935	Entire period	Calculated number of pears per bu. (45 lb.)
		Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*	
Cultivation with cover crop (plowing)	A- 1	4.6	4.6	3.7	4.7	4.3	168.3
	A- 8	5.4	4.2	3.7	4.8	4.1	174.8
	A-15	6.2	5.0	3.4	4.3	3.9	182.5
	Average	5.4	4.6	3.6	4.6	4.1	175.2
Cultivation with cover crop (disking)	E- 5	3.8	4.1	3.7	4.6	4.2	170.5
	E- 9	6.0	4.6	4.6	4.6	4.6	156.6
	E-11	6.0	4.6	3.4	4.4	4.0	177.6
	Average	5.3	4.4	3.9	4.5	4.3	168.2
Grass and straw mulch	C- 3	6.1	3.7	4.5	5.1	4.9	146.8
	C- 6	5.1	3.4	4.6	5.0	4.8	149.0
	C-13	5.9	3.6	4.2	4.4	4.4	164.4
	Average	5.7	3.6	4.4	4.8	4.7	153.4
Bluegrass sod with nitrogen	B- 2	3.8	4.1	3.6	5.2	4.4	164.4
	B- 7	5.3	2.9	4.0	4.9	4.5	159.0
	B-14	4.7	.....	3.1	4.8	3.8	188.7
	Average	4.6	3.5	3.6	5.0	4.2	170.7
Alfalfa sod	D- 4	.....	3.0	3.5	4.5	4.2	169.3
	D-10	2.4	3.2	3.5	4.2	4.1	175.4
	D-12	3.2	1.6	2.8	4.0	3.8	191.5
	Average	2.8	2.6	3.3	4.2	4.0	178.7

very inadequate cross pollination. There is little doubt but that the trees in cultivation would have produced a somewhat larger yield than the trees in grass mulch had all the flowers been thoroughly cross pollinated. The few fruits on the cultivated trees had a greater average weight than those from any other treatment; on the other hand, the fruits from the trees in alfalfa had the lowest average weight per fruit.

In 1934, the flowering was quite abundant on all plots and, as previously indicated (Table 12), the fruit setting was very satisfactory. Consequently, in order to prevent over bearing, some fruits were removed by thinning; the proportion of the total number taken from the trees is shown in Table 15. It is to be noted that practically the same percentage (27 to 29 per cent) of the total number was removed from the trees in the cultivated and in the mulched plots. On the other hand, due to lighter flowering of the trees in the bluegrass sod and in alfalfa, a smaller proportion of the total number was removed. At harvest the greatest average yield per tree (Table 13) was from the trees in the cultivated-plowed plots (19.6 pounds), followed by the trees in the cultivated-disked plots (17.1 pounds). The yield of the trees in grass mulch averaged 13.9 pounds per tree. On the other hand, the yield of the trees in bluegrass sod was only 6.5 pounds per tree but was nevertheless double that from the trees in alfalfa. On the basis of number of pears produced per tree the yield of the cultivated, as compared with the mulched, trees was even more marked. That the fruits were larger on the trees in grass mulch is definitely shown by the weights given in Table 14, in which it is to be noted that the fruits in grass mulch averaged 4.5 ounces per fruit while the fruits in the cultivated-plowed and in the cultivated-disked plots averaged 3.7 and 4.0 ounces per fruit, respectively. The fruits from the trees in bluegrass sod averaged 3.6 ounces while those from the trees in alfalfa showed an average weight of only 3.3 ounces.

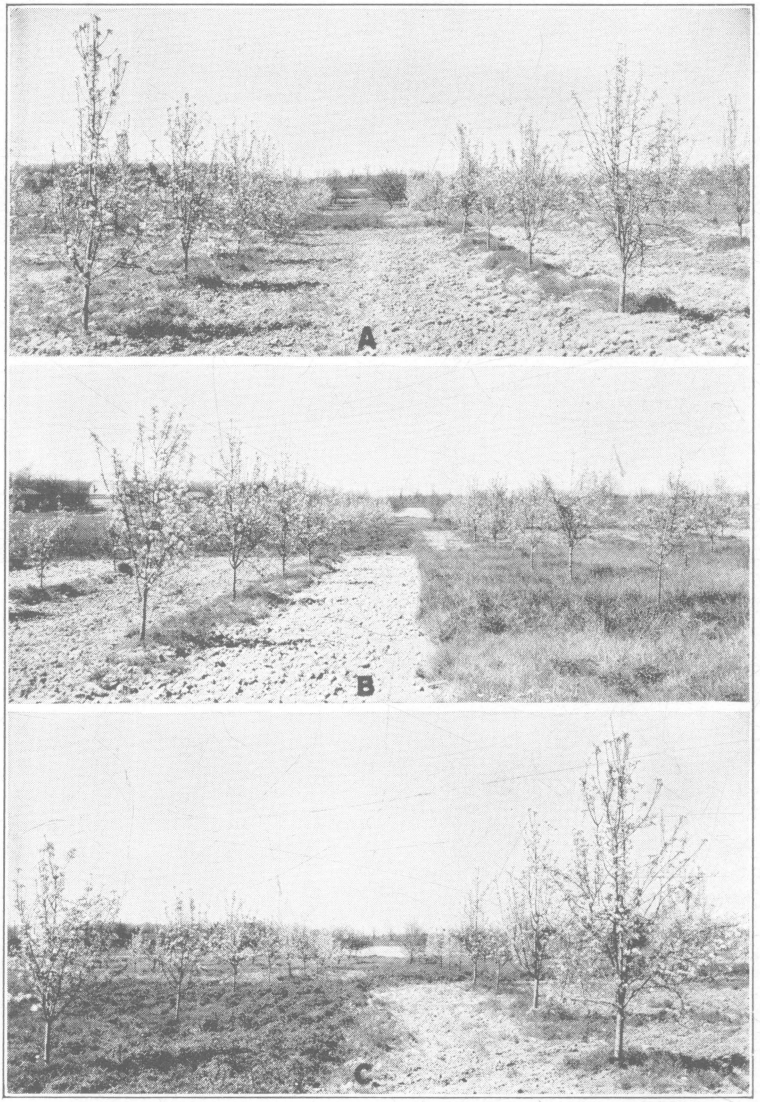

Fig. 4.—A. *Left*—**Cultivated plot E-9;** *Right*—**Cultivated A-8 May 1935. B.** *Left*—**Cultivated plot A-15;** *Right*—**Bluegrass sod B-14 May 1935. C.** *Left*—**Alfalfa D-10;** *Right*—**Cultivated E-9 May 1935.**

Finally, in 1935 the number of flowers produced was heavy on the trees in all plots. The heavy flowering of the trees in alfalfa may possibly have been the result of the rather severe moisture deficiency characterizing the growing season of the previous year. No fruits were removed by thinning in view of the relatively favorable moisture conditions in June and July. The total weight of fruit was highest on the mulched trees, with 28.7 pounds per tree

(Table 13). That from the trees in the cultivated-disked and the cultivated-plowed plots was 24.9 and 23.3 pounds, respectively. On the other hand, the yield from the trees in alfalfa was 17.7 pounds per tree, as compared with 9.1 for the trees in bluegrass sod. The greatest number of fruits per tree was also produced by the mulched trees (96 per tree as compared with 88 and 82 on the trees in the cultivated-disked and cultivated-plowed plots). The weight per fruit as shown by the data in Table 14 was quite satisfactory on all plots. The fruits from the bluegrass sod and from the mulched trees weighed the most; those from the cultivated plots were next in weight. The fruits from the trees in alfalfa weighed slightly less on the average than those from the cultivated trees but the weight was satisfactory.

TABLE 15.—Proportion of Pear Fruits Removed in Thinning—1934

Treatment	Plots	No. of trees	Total number of fruits removed		Grand total	Per cent of total removed by thinning
			By thinning	Harvested		
Cultivation with cover crop (plowing)	A- 1	10	330	747		
	A- 8	15	637	1730		
	A-15	12	233	821		
Total		37	1200	3198	4398	27.3
Cultivation with cover crop (disking)	E- 5	12	166	582		
	E- 9	14	376	1076		
	E-11	12	458	994		
Total		38	1000	2652	3652	27.4
Grass and straw mulch	C- 3	11	194	413		
	C- 6	15	365	953		
	C-13	12	254	594		
Total		38	813	1960	2773	29.3
Bluegrass sod with nitrogen	B- 2	12	81	322		
	B- 7	15	122	492		
	B-14	12	120	324		
Total		39	323	1138	1461	22.1
Alfalfa sod	D- 4	11	67	216		
	D-10	14	71	192		
	D-12	12	40	174		
Total		37	178	582	760	23.4

Table 13 also gives the total number and weight of fruits produced over the entire bearing period, 1932 to 1935, inclusive. It is to be noted that the total yield per tree in the cultivated plots has averaged 44.8 to 45.1 pounds, as compared with 43.1 pounds for the trees in the mulched plots. This difference is definitely not significant. The trees in alfalfa were next in order with a yield of 21 pounds per tree; the trees in bluegrass sod have the lowest average yield, 16.3 pounds per tree. The comparatively favorable position of the trees in alfalfa in regard to total yield, as compared to those in the bluegrass sod, is largely the expression of the relatively high yield in 1935.

Examination of the data for number of fruits (Table 13) shows that the trees in cultivation have produced what would seem a significantly greater number of fruits per tree than the trees in mulch. The trees in alfalfa produced a greater number of fruits per tree than the trees in bluegrass sod. Comparison of the average weight of fruits, as presented in Table 14, definitely

indicates that the smaller number of fruits per tree on the mulched plots has been compensated for by the greater average weight per fruit. The fruits have averaged 4.7 ounces each, as compared to 4.3 and 4.1 ounces per fruit from the trees in the cultivated-disked and the cultivated-plowed plots, respectively. It is also interesting to note that the fruits from the trees in bluegrass sod have shown almost the same average weight as those from the trees in cultivation (4.2 ounces). On the other hand, the fruits from the trees in alfalfa have shown the smallest weight, 4 ounces per fruit. Calculating these differences in size on the arbitrary basis of 45 pounds to a bushel, one finds that a bushel of fruit from the mulched trees averaged 153 fruits, as compared with 168 and 175 from the cultivated-disked and the cultivated-plowed plots, respectively. The average number from the trees in bluegrass sod was 170 per bushel, as compared with 179 for the trees in alfalfa. It should be noted that the favorable size of fruit from the trees in the bluegrass sod, considered over the 4-year period, is due largely to their large size in 1935 when the water supply was not deficient.

YIELD OF FRUIT IN RELATION TO GROWTH OF TREE

Table 16 presents data for the weight of pears in relation to tree growth as indicated by the gain in cross-sectional area of the trunk. Values are given for the years 1932 and 1933 but, due to the small amount of fruit produced, are not considered in detail in the text. It is obvious that the trees in mulch and in alfalfa did not produce during 1932 and 1933 as high yields in relation to their growth as the trees in the other treatments. However, in 1934, the first year of a really satisfactory yield considering the age of the trees, the trees in the cultivated-plowed plots produced 15.5 pounds of fruit to a gain of one square inch in the cross-sectional area, as opposed to 11.8 and 10 pounds per tree for the trees in the cultivated-disked and mulched plots. Next in order came the trees in bluegrass sod with 7.8 pounds, followed by the trees in alfalfa with only 4.2 pounds of fruit for a gain of one square inch. In 1935, the trees in grass mulch and in alfalfa gave the highest yields in relation to growth (18 2 and 16.2 pounds, respectively); the trees in bluegrass sod again showed a very unsatisfactory yield (9.1 pounds). The trees in the cultivated plots produced 14.3 to 14.7 pounds to a gain of one square inch.

TABLE 16.—Weight of Pears in Relation to Gain of 1 Square Inch in Area of Cross Section of Trunk, 1932-1935

Treatment	Plot	Production in relation to gain of 1 sq. in. in area of cross section				
		1932	1933	1934	1935	Average
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Cultivation with cover crop (plowing)	A	1.0	1.1	15.5	14.3	8.9
Cultivation with cover crop (disking) . .	E	1.6	1.2	11.8	14.7	8.7
Grass and straw mulch .	C	0 2	0.3	10.1	16.2	8.8
Bluegrass sod with nitrogen	B	1.1	0.2	7.8	9.1	5.6
Alfalfa sod	D	0.2	0.1	4.2	18.2	8.5

Finally, on the basis of the period from 1932 to 1935, inclusive, the trees in the cultivated and mulched plots have practically identical values for yield in relation to growth; namely, 8.7 to 8.9 pounds of fruit to a gain of one square

inch in cross-sectional area. As a result of their high yield in 1935, the trees in alfalfa followed with 8.5 pounds; the trees in bluegrass sod showed the lowest yield with only 5.6 pounds of fruit. This comparison then very definitely shows that the trees in the cultivated-plowed, cultivated-disked, and mulched plots have produced the largest yield in relation to growth and these treatments have been the only satisfactory ones in this experiment. On the other hand, the trees in bluegrass sod have produced a very unsatisfactory yield even in relation to their growth. The trees in alfalfa showed a surprisingly high yield in relation to their growth. Their growth is improving possibly as a result of mulching in 1934 and of the favorable moisture condition during 1935.

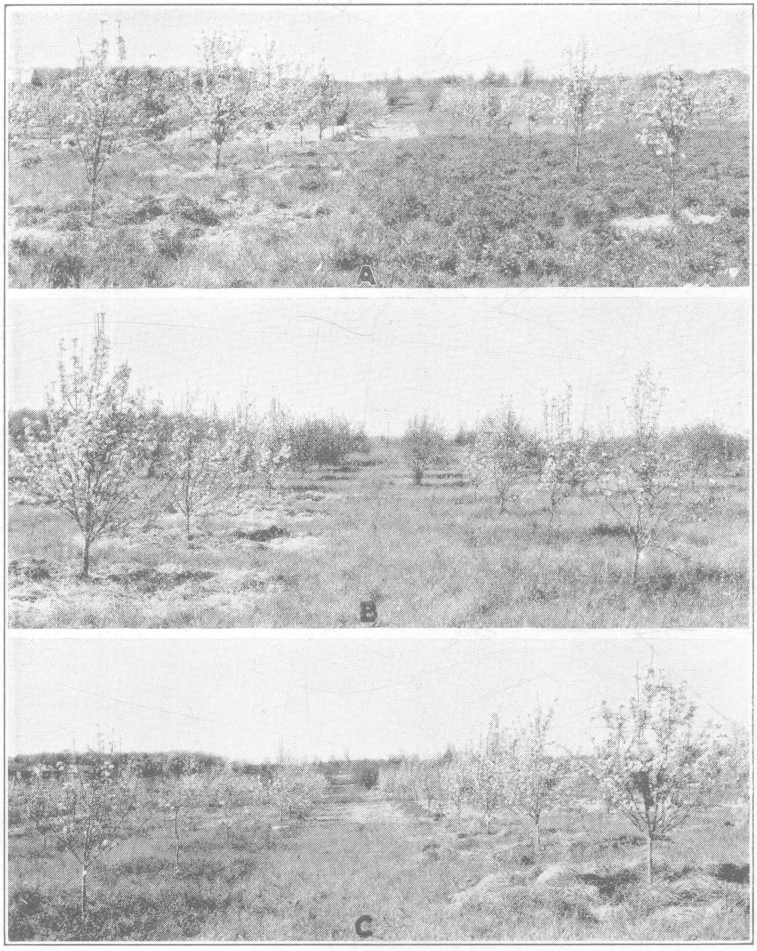

Fig. 5.—A. *Left*—**Grass and straw mulch C-13;** *Right*—**Alfalfa D-12 May 1935. B.** *Left*—**Grass and straw mulch C-3;** *Right*—**Bluegrass sod B-2 May 1935. C. Comparison of growth of trees in bluegrass sod with those in mulch.** *Left*—**Bluegrass sod plot B-14;** *Right*—**Mulch plot C-13.**

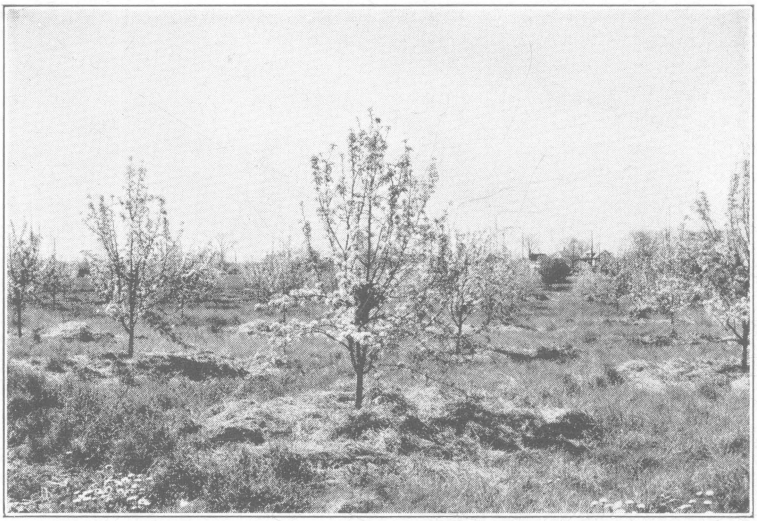

Fig. 6.—Trees in mulched plot C-6, May 1935

In Table 17 are presented the relative growth, yield of fruit, and weight of prunings from trees in the various plots, in comparison to the cultivated plots as 100.

TABLE 17.—Growth, Yield, and Weight of Prunings of Trees in Mulch, Bluegrass Sod, and Alfalfa in Relation to the Cultivated Trees as 100

Treatment	Gain in cross-sectional area of trunk	Number of fruits	Total weight of fruits	Weight of prunings
Cultivated plots (A and E)	100	100	100	100
Grass and straw mulch	93	86	96	77
Bluegrass sod with nitrogen	58	35	36	18
Alfalfa	47	49	47	11

In this table it is to be noted that there is surprisingly good correlation between the growth of the trees in the various treatments and their yield, particularly when the yield is based on the total weight. No particular evidence was obtained to indicate that the growth of the trees in cultivation had reached the point where it failed to be associated with an increased yield. It is interesting to note, however, that the yield of the trees in bluegrass sod lagged behind growth, a situation which was different from that found in the plots of the other treatments.

DISCUSSION

EFFECT OF SOIL MOISTURE UPON TREE RESPONSE

In the interpretation of the results obtained from the experiment reported in this bulletin, it is important to remember the fact that the rainfall was deficient by more than 0.5 inch during 8 of the 15 months, from May to July inclusive, during the period of the experiment. This deficiency was reflected in the low soil moisture in those plots where vegetation occupied the surface soil. The significance is not in the fact that soil moisture in the bluegrass sod and the alfalfa plots was lower but in the fact that it was so low as to reach the wilting percentage rather frequently. For example, the soil moisture content during the dry periods of 1932 and 1934 reached the low values of 8 to 9 per cent (Tables 7 and 8). Two other facts lead to the same conclusion. In the first place, the nitrate content of the soil taken beneath the trees was in excess at all times and was particularly high under the bluegrass sod where the trees made exceedingly poor growth. Secondly, the trees in the plots making the slower growth showed no evidences of a deficiency of organic nitrogen. The leaves were dark green at all times and the color of the bark was similar to that of the trees growing in the cultivated and mulched treatments.

DEPTH OF ROOTING IN RELATION TO SOIL MOISTURE

The depth of rooting of the trees is an important factor in determining the extent to which growth was restrained by the deficiency of soil moisture. The soil profile was examined in different plots in the spring of 1936. The depth of rooting was definitely variable but as far as could be ascertained was comparatively shallow. Occasionally, fairly thick roots (one-quarter to one-half inch in diameter) penetrated to a depth of 24 or more inches, but, in general, the root population was confined to the upper 2 feet. This comparatively shallow rooting was due not only to the fact that the trees were young but also to the compact nature of the soil. It was noted in the majority of observations that a characteristic yellowish-brown layer began at the 10 to 12-inch depth. Beneath this layer at a depth of 18 inches, a grey layer, characteristic of a poorly aerated condition, usually existed. Examination also showed that the alfalfa roots were quite concentrated in the upper 2 feet, even though a considerable number extended into soil beneath the rooting area of the trees. In view of the intense competition for water on the part of the alfalfa and bluegrass roots with those of the trees, it is not surprising that the tree growth was unusually poor. No indication was obtained that alfalfa "conserved the water in the upper soil horizons", as suggested by Collison and Harlan (5) in their report on soil management systems for the apple in New York.

Furthermore, the fact that in this experiment the trees were somewhat shallow rooted should also be kept in mind in consideration of the application of the results to pear culture in general. It is undoubtedly true that, as the depth of rooting increases, the detrimental effect of surface vegetation upon the growth of trees is reduced. This effect would likely be reduced as the trees become older, except in locations where root growth is definitely confined to the surface and upper subsoil horizons by inability to penetrate the lower subsoil 3 to 6 feet beneath the surface. In this experiment, relatively shallow rooting with its concomitant low soil moisture reserve was compensated for either by the removal of surface vegetation beneath the trees or by the appli-

cation of a surface mulch. As a result, the growth of the mulched and cultivated trees was not only much less restrained but was also satisfactory from a practical standpoint.

USE OF ALFALFA IN YOUNG PEAR ORCHARDS

In this experiment alfalfa sod greatly restrained the growth of young pear trees, not only because it induced considerable soil moisture deficiency but also because it encouraged the development of the Buffalo tree hopper. This insect principally attacked the trees in alfalfa since only a few other trees in the entire planting were affected.

It seems reasonable to conclude that the planting of alfalfa in a young pear orchard will usually result in considerable reduction in tree growth if environmental conditions are of such a nature that the alfalfa reduces the soil moisture to a considerable extent. In this connection it is to be recalled that Kinman and Magness (12) conclude that alfalfa will invariably produce too great a reduction in tree growth unless the water supply is rather abundant and the rooting of the trees quite deep. Hunter (11), in his report of experiments at the Summerland Experiment Station in British Columbia, states that alfalfa has produced unfavorable results in both apple and stone fruit orchards. He particularly advises against the use of alfalfa in shallow soils or where water is likely to be limited. However, where there is considerable rainfall during the growing season and so long as the soil permits continuously deeper rooting of the trees, the detrimental effect of the alfalfa is lessened. The extent of reduction in tree growth in any alfalfa planting cannot be predicted without information as to the texture of surface soil and subsoil, the depth to which trees commonly root in that particular soil, and the depth of the water table. Furthermore, weather records giving the proportion of growing seasons deficient in rainfall and the amount and intensity of sunshine in the particular region will have some value. In this connection Ohio pear growers should keep in mind that the precipitation records for the past 75 years indicate that rainfall has been deficient for at least 1 or 2 months during a considerable number of the growing seasons. Moreover, the soils in northern Ohio where pears are commonly grown are, in general, of two types: Either a sandy loam with a consequently lower soil water reserve or the heavy type, such as the Mahoning or Trumbull silty clay loams, which because of their heavy, compact subsoil prevent deep rooting.

The use of alfalfa as a mulch has received little experimental attention and the experiment reported herein is to be continued. It would seem reasonable to predict that, if the alfalfa used for mulch is grown completely outside the outer fringe of tree roots and is applied in amounts sufficient to kill all vegetation over the surface area above the tree roots, there should be no undue restraint of tree growth. In fact, the question arises as to the possibility of a too pronounced stimulation of tree growth because of the supply of nitrogen constantly liberated from the organic nitrogen of the decaying leaves and stems of the alfalfa. Insofar as an extremely succulent growth is induced, the hazard of rapid fire-blight movement in the pear tissues becomes serious. Until more evidence has been obtained, it would appear wise to use alfalfa mulch for pear trees with considerable caution.

USE OF CULTIVATION WITH COVER CROP IN YOUNG PEAR ORCHARDS

The extent to which the cultivation with cover crop system permits more favorable soil moisture conditions largely governs the degree to which it possesses advantages over sod with added nitrogen. Unfortunately, however, increased growth often occurs at the expense of reduced resistance to the ravages of fire blight. In the more succulent tissue the fire-blight organism spreads rapidly, and frequently an almost complete destruction of trees has resulted from changing a pear orchard from sod to cultivation.

It has been observed that where pear plantings are isolated from apple orchards and where no overwintering blight cankers are allowed to remain on the pear trees, the pear may be grown in cultivation for a number of years with little or no serious injury from blight. As soon as the grower has observed a few flowering shoots affected by the disease, these have been immediately removed and thus the spread of the disease has been prevented. It is in such an isolated location that cultivation with cover crops has resulted in no serious inroads of the disease. On the other hand, where pear trees are adjacent to an apple orchard which may carry overwintering cankers year after year, cultivation with a cover crop has frequently encouraged rapid and disastrous spread of blight. Consequently, it would seem wise to adopt the cultivation with cover crop system only in locations most favorably situated from the above point of view. Furthermore, wherever another system which will moderately restrain growth of the trees can be followed, such a system should be adopted.

In this experiment the trees grown in cultivation but with the soil disked instead of plowed in the spring produced as good results as where the soil was plowed yearly. It would appear that wherever cultivation is carried out the practice of disking may be adopted.

USE OF BLUEGRASS SOD WITH ADDED NITROGEN IN YOUNG PEAR ORCHARDS

Whether bluegrass sod is adapted to particular locations and soil types depends upon the extent to which the soil moisture is depleted. Where moisture is not a limiting factor this method of soil management is quite satisfactory. The only exception is in the case of very dense sod which demands an excessive application of nitrogen.

In view of the fire-blight hazard it would seem advisable to adopt the bluegrass sod system despite some restraint in tree growth. On the other hand, where the water is low in the area occupied by the roots and rooting is comparatively shallow, too great restraint in growth may develop, thus necessitating the selection of some more favorable system of soil management, such as grass mulch.

The grower should understand that adoption of the bluegrass sod system does not at all insure that the trees will be resistant to fireblight. Shoots of trees in sod may be as succulent early in the season when the blight organism has gained entrance to the tissues as shoots of a tree in cultivation. Furthermore, it is always difficult to judge the amount of nitrogen which will produce sufficient but not excessive growth.

This bulletin is not concerned with the form of nitrogen which should be used on the bluegrass sod to maintain the nitrogen requirements of the tree. Growers should note that some of the more recent recommendations advise the use of the more readily available, quick acting forms. The basis for this rests upon the premise that early shoot and leaf development is to be encouraged but that it is not desirable to encourage such growth during the early summer, since such a practice is more conducive to rapid movement of the fire-blight organism through the tissues. Undoubtedly, encouraging succulent growth during late June and early July does produce this effect. However, in fairness to all points of view it should be kept in mind that fire-blight organisms usually obtain entrance at the time of pollination and begin to spread rapidly from 10 days to 4 weeks thereafter. It is very questionable whether any nitrogen-carrying fertilizer, regardless of its availability and its earliness of application, has completed its effect upon growth as early as the period from May 22 to June 10. In view of this the writer is not prepared to distinguish between nitrate of soda and ammonium sulfate as nitrogen-carrying fertilizers upon the basis of our present evidence.

The amount of nitrogen fertilizer will naturally depend upon several factors, such as the fertility of the soil, present vigor of the trees, the type and amount of growth made the previous year, amount of grass (density of the sod), age of the trees, and soil type. The procedure should involve starting with a small amount and adding increased increments from year to year, as the growth of the trees the previous year may indicate. For the non-leguminous sod fertilization should begin with no more than one-fifth to one-quarter pound per year of the tree's age. Even this increment may prove to be too much and it may not seem advisable to increase the amount per tree for several years. If more nitrogen is necessary, the trees will show evidences of a slight deficiency. No attempt should be made to keep the growth a very dark green, and the production of long, willowy, succulent shoots is not to be encouraged.

GRASS AND STRAW MULCH AS A SOIL MANAGEMENT SYSTEM FOR THE PEAR

In response to the favorable soil moisture conditions induced by mulch, growth and fruiting as satisfactory as with cultivation and cover crop were obtained. In fact, at the end of the 5-year period the trees in mulch were more uniform in growth than those of any other treatment. In the writer's judgment the most impressive treatment, taken as a whole, was the mulch system of soil management.

In considering the application of this system to pear culture in general and with particular reference to Ohio, it is important to keep in mind the soil type—the Mahoning silty clay loam. This soil is not confined merely to the locality where this experiment was conducted but is quite generally found in Lake County and, together with the Trumbull silty clay loam, is the type upon which the pear is frequently grown. These types are characterized by "compact impervious subsoil layers" which greatly impede water drainage and are not favorable for extensive root penetration. In these soils the water supply is usually sufficient during the early part of the growing season but the water available for tree growth is limited by the comparatively shallow depth of soil into which the roots penetrate. With frequent periods of deficient rainfall and with surface vegetation transpiring considerable quantities of water, it is not

surprising that the moisture supply of the soil eventually falls to the critical point where growth of the tree and of the fruit is affected. In view of these facts, it does not seem surprising that bluegrass sod with added nitrogen depressed tree growth over a 5-year period containing such a high proportion of months deficient in rainfall as occurred at Strongsville from 1931 to 1935, and it is under such conditions that the mulch system has an advantage with its more favorable soil moisture supply. It can be established by applying the material which grows between the trees to the surface area above the roots, with other mulching material added as needed.

It should be kept in mind that, insofar as the mulch system permits greater growth, it is more favorable to rapid growth of the blight organisms in infected tissues. Whether or not the shoots were as succulent on the trees in the mulched plots as in the cultivated plots cannot be stated. There is little question but that the pear grower must choose between two situations in pear culture. Nothing in this bulletin is intended to encourage pear growers who are successfully using the bluegrass sod method of soil management to change to the mulch system. The writer's primary purpose is to present evidence concerning the relative growth and fruiting of trees in the various systems.

The amount of material required to establish and maintain an adequate mulch is frequently the limiting factor in its application to tree culture. Blake (2) has estimated that 1 pound of mulching material to 3 square feet of surface area is necessary to maintain a satisfactory mulch in New Jersey. At Wooster the available data indicate that 1 pound of dry material to 3 or 4 square feet would be the maximum amount required to maintain an excellent mulch. Mulching material applied at a rate considerably less would likely produce favorable results.

THE MULCH SYSTEM IN OTHER SOIL MANAGEMENT INVESTIGATIONS

The very favorable soil moisture condition induced by the mulch is similar to the results obtained in several experiments with young apple trees. Green and Ballou (10) found 30 years ago at Wooster that young apple trees grown in "sod mulch" made more uniform growth and were not only heavier than trees grown in sod culture but also heavier than those in cultivation with cover crops. They report that the growth of the mulched trees "was uninterrupted" during the growing seasons from the time of planting in 1901 to the end of the experiment in 1906. Examination of the rainfall records from 1901 to 1906, presented by Alexander and Patton (1), during the period from April to September, inclusive, (30 months) shows that the rainfall was appreciably below the average during 12 months of the growing season in Green and Ballou's experiments. Stewart (17) in Pennsylvania 10 years later presented data showing that young apple trees up to 7 years of age grown in mulch alone, in mulch with manure, and with commercial fertilizers made as large gains in circumference of the tree trunk as trees grown in cultivation with cover crops and with manure. It is true that the mulched trees receiving the manure and the commercial fertilizers made a slightly greater growth and produced a considerably higher yield than trees in mulch alone, a fact which showed that nitrogen was not abundant in the poor soil of this orchard. However, the importance of the considerably higher moisture content in the soil beneath the mulch is indicated by Stewart, who states that "the roots of the mulched trees were surrounded with 85 to 90 per cent of the best possible moisture content even in

September 1915 after fully six weeks of very unusual drouth while the soil around the roots of the tilled trees in most cases had been reduced to a dust-dry condition." Woodbury, Noyes, and Oskamp (21) presented their results on the growth of young trees of four apple varieties planted in 1909 during the period from 1912 to 1916. The rainfall during the months of May, June, and July was deficient during 10 out of the 15 months of the experiment. The moisture content of the soil under the straw mulch was double that of the grass plots, which reached the low value of 6.1 per cent by the middle of June in 2 of the 5 years of the experiment. Consequently, the authors concluded that the tree growth was reduced by the low soil moisture in the plots where the soil was not cultivated or mulched. Morris (15) reported that mulching apple trees in Washington displaced two irrigations out of five. Furr and Magness (9), as a result of some comparisons of the fruit growth of mature trees in irrigated, mulched, and cultivated plots in Maryland during the dry year 1930, report that fruits in the dry mulched plots made greater growth than those on trees in the dry cultivated and dry alfalfa plots. The growth of the fruit on the dry mulched trees was only exceeded by that of fruits on trees in plots receiving irrigation. Wiggans (20) reported that young Stayman Winesap trees growing in straw mulch produced greater growth than trees in cultivation. Faurot (8), at Mountain Grove, Missouri, as a result of soil management experiments on a young apple orchard during its first 12 years, reported that straw mulch produced trees with a greater weight of tops and roots, a greater gain in trunk circumference, and a higher total average production than trees in tillage or in sod with added nitrogen. In an older orchard, straw mulch was also superior in both the growth and yield which it induced. Finally, in 1935, Magness, Degman, and Furr (14) gave a final report of their irrigation and moisture experiments in some eastern orchards during 1930 to 1932. The fruits on the dry but mulched trees were usually larger than those from the dry cultivated trees. However, irrigation of both mulched and cultivated trees produced the most favorable response in growth, yield, and size of fruit due to the considerable deficiency of moisture in the comparatively shallow soil in which the trees were grown.

That bluegrass and alfalfa draw heavily on the moisture of the surface soil has been indicated by the results of Clark (4) and Fagan, Anthony, and Clark (7) in Pennsylvania. They report a much greater withdrawal of water from the soil under alfalfa during dry periods from May to October than from leguminous and non-leguminous cover crops. Alfalfa was particularly active in depleting the soil moisture. Kinman and Magness (12) declare that the use of permanent cover crops for pears has not become popular in the West in those locations where water is none too abundant. Even where sufficient water is available, the usual practice has consisted of disking the alfalfa in the spring and cultivating the soil thereafter in order to incorporate the material into the soil. They state that this procedure is for the purpose of holding the cover crop in check during the periods of rapid tree growth and fruit setting, in order to alleviate the competition between the roots of the alfalfa and of the tree.

Evidence is present in the literature indicating that alfalfa and bluegrass do not decisively restrain the growth of the trees under all conditions and in all locations. In the experiments reported by Lyon, Heinicke, and Wilson (13) the growth of young, closely planted apple trees was measured during 1919 and 1920. They show that the soil moisture beneath trees in sod was lower than beneath the trees in cultivation, but the difference was not great. In

fact, the values shown were not sufficiently low to indicate that soil moisture was a factor inhibiting the growth of the trees. The lowest soil moisture percentage given was 11.3 which, in this particular soil, was probably somewhat higher than the wilting percentage. Collison and Harlan (5) report the effect of several orchard covers upon the growth of apple trees 20 to 26 years of age. The period covered by the observations was from 1926 to 1931. The nitrate and moisture contents were given only for the year 1929. The treatments were cultivation, cultivation with reseeding to red clover, alfalfa sod, and grass sod. During June and early July of 1929, the moisture content under the latter three treatments was lower than under cultivation but the differences were small. The authors state that "growth, foliage characters, and fruit production on these plots show that there has been no greater lack of soil moisture on one plot than on another during these five years". They also state that the dry season of 1930 was not "reflected in reduced terminal growth of one plot over another in this orchard nor did the trees apparently suffer from lack of moisture from any observational viewpoints". This condition under alfalfa and under grass in which the growth was unaffected must have been due, as indicated by the authors, to the deep rooting of these mature trees.

SUMMARY

The growth and fruitfulness of young Bartlett pear trees growing in four systems of soil management have been observed over the 5-year period, 1931 to 1935. The systems used were:

(a) Cultivation with cover crop (three plots plowed and three plots disked).
(b) Kentucky bluegrass sod with added nitrogen.
(c) Grass and straw mulch.
(d) Alfalfa sod.

Each treatment (12-15 trees) has been triplicated over the relatively level 2-acre area included in the experiment. The soil is a Mahoning silty clay loam and the subsoil is quite impervious, thus preventing deep rooting.

The principal data taken during the course of the experiment were: (a) circumference at base of trunk, (b) weight of prunings per tree, (c) total number and weight of fruits per tree, (d) soil moisture and nitrates in various plots, (e) percentage of flowers which developed into fruits after the last drop, (f) height and breadth of trees at the end of the experiment, and (g) yield of alfalfa in alfalfa plots.

The principal results obtained were as follows:

The gains in the cross-sectional area of the trunks of the trees in the cultivated-plowed, cultivated-disked, and mulched treatments were not significantly different at the end of the 5-year period. The values were 5.82, 5.64, and 5.41 square inches, respectively. On the other hand, the gain of the trees in the bluegrass sod was 62 per cent of that of the trees in mulch. The gain of those in alfalfa was 51 per cent of that of the trees in mulch. From a commercial viewpoint the growth of the trees in the bluegrass and alfalfa sods would be considered unsatisfactory.

There was no significant difference in the average height and width of head of the trees in the cultivated-plowed, cultivated-disked, and mulched treatments. On the other hand, the trees in the bluegrasss sod and in alfalfa averaged considerably less in these respects, as would be expected from the data on trunk circumference.

At the end of the 5-year period a somewhat greater total weight of prunings had been removed per tree from the cultivated plots than from those in the mulch. The value for the trees in the cultivated treatment was approximately 3.4 pounds. The total amount removed per tree from the mulched trees averaged approximately 2.6 pounds; the total amounts from the trees in bluegrass sod and alfalfa have averaged approximately 10 and 6 ounces, respectively.

In general, the percentage of flowers which developed into fruits after all dropping had ceased was not appreciably different on the trees in cultivated, mulched, and bluegrass sod treatments. There appeared to be a small reduction in set on the trees in alfalfa sod.

The total weight of fruit from the trees in the cultivated and mulched treatments was not significantly different. The average per tree in the cultivated plots was 45 pounds, as compared with 43.7 from the trees in the mulched plots. Next in order was the yield from the trees in alfalfa, a total of 21 pounds per tree; the trees in bluegrass sod with added nitrogen produced the lowest average yield, 16.9 pounds per tree. It should be kept in mind that the trees were young and in reality just coming into bearing.

On the basis of number of fruits, the trees in the cultivated plots produced a greater number per tree than those in mulch. The trees in alfalfa also produced a greater number of fruits per tree than those in bluegrass sod with added nitrogen.

The average fruit from the mulched trees was larger than from those in the other treatments. Calculating the differences in size on the arbitrary basis of 45 pounds to a bushel, a bushel of fruits from the mulched trees averaged 154 fruits, as compared with 167 and 178 from the cultivated-disked and the cultivated-plowed plots, respectively. The average number from the trees in bluegrass sod was 167 per bushel and for the trees in alfalfa, 178.

Disking in the cover crop in the spring followed by cultivation produced as good results in growth and fruiting as plowing followed by cultivation.

Low soil moisture was the principal factor limiting the growth of the trees in the bluegrass sod and alfalfa treatments, reaching rather frequently the wilting percentage of 9.5. However, in the case of alfalfa sod the Buffalo tree hopper was in part responsible for the small size of the trees at the end of the 5-year period.

The depth of rooting of the trees was definitely variable but as far as could be ascertained, comparatively shallow. This was due not only to the fact that the trees were young but also to the compact nature of the lower subsoil.

It seems reasonable to conclude that the planting of alfalfa in a young pear orchard will usually result in considerable reduction in tree growth if environmental conditions are of such a nature that the alfalfa reduces the soil moisture to a considerable extent.

Although the cultivation with cover crop system will permit satisfactory growth and fruiting of the pear, it also induces a rather succulent type of growth somewhat more susceptible to fire blight. Hence, this system of soil management is not recommended where fire blight is a serious hazard.

The extent of the deficiency in soil moisture induced by bluegrass sod is pertinent in determining the applicability of this system to particular locations and soil types. Where these factors are favorable from a moisture viewpoint the bluegrass sod with added nitrogen method of soil management becomes most satisfactory. In view of the hazard of fire blight it would seem advisable to adopt this system despite some restraint in the growth. On the other hand, under conditions such as those reported in this bulletin, where the soil moisture deficit is considerable and the rooting is confined to shallow surface layers, too great restraint in growth may develop, thus necessitating the selection of some system of soil management more favorable to tree growth.

Since the trees in mulch had made a growth and fruiting equal to that of the trees in cultivation, the application of this system of soil management to the culture of young pear trees becomes a matter of importance under conditions where low soil moisture is frequently the most important factor limiting tree growth. It is under such conditions that it has its most pertinent application.

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